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An Improved Design of Contract Net Trust Establishment Protocol

Aarti Singh[1], Dimple Juneja[2]
[1,2] MMICT & BM, MMU, Mullana, Haryana, India
Email: {singh2208[1], dimplejunejagupta[2]}@gmail.com

***Abstract*— Contract Net Protocol (CNP) is FIPA standardized high level communication protocol which specifies the way software agents should follow while communicating. However it lacks methods for ensuring trust and reliability of the agents participating in the communication. In an earlier paper authors proposed a variation of CNP involving trust establishment feature into it, termed as Contract Net Trust Establishment Protocol (CNTEP). However, efficient communication can not be ensured unless the communicating counterpart is reliable. This fact provided the motivation for the present work, which extends CNTEP and incorporates reliability computation component in it.**

***Index Terms*— CNP, FIPA, CNTEP, Trust, Reliability, Agent Communication, Agent Communication Protocol.**

I. Introduction

Agents are widely been employed in critical applications like e-commerce, web personalization etc. A single agent is unable to provide complex services desired by the user, thereby giving rise to social communities of agents termed as Multi-agent systems (MAS). Multi-agent systems are serving as instruments in many web based applications, where they need communication among agents to place together the independent pieces of knowledge drawn from diverse sources into meaningful form. For agent communication FIPA[1] standardized Contract Net Protocol [2] is most commonly employed protocol where FIPA is a Foundation for Intelligent Physical Agents, a nonprofit organization working towards standardization of agent development platforms and communication protocols. Although CNP[11] addresses most of the issues related to agent communication, it did not provide any means for establishing trust among communicating counterparts which is very essential for agents operating in dynamic, distributed and open environments where any agent is free to enter or leave a MAS at its own aspiration. It also doesn't enforce any prerequisite for ensuring reliability of the participating agents. Since agents are by nature self-centered and work for accomplishment of their own goal, all of them might not be reliable all the time. Lack of procedures for ensuring trust and reliability of agents are major barrier towards optimal utilization of this promising technology.

This work is an extension of our earlier work in which authors proposed a variation of CNP incorporating trust establishment feature into it, which was termed as Contract Net Trust Establishment Protocol (CNTEP) [10]. This work laid down the procedure for establishing trust among perspective communication counterparts, which could lead to more reliable outputs. However reliability of participating agents was not paid much attention. Reliability of agents participating in communication, who will later be performing parts of critical tasks, is also equally crucial. Even if an agent is trustworthy doesn't guarantee that it is reliable too and will provide the desired results within specified time. Aim of this work is to extend CNTEP to incorporate reliability computation mechanism in it so that an agent will be delegated a job iff it is reliable, leading to better system performance.

This paper is structured as follows: section II explores the literature in the field of interest, Section III elaborates the proposed reliability calculation mechanism termed as RCNTEP. Finally section IV concludes the work.

II. Literature Survey

Bui, Venkatesh & Kieronska (1998) [3] demanded sharing of private knowledge of agents to each other for trust establishement. Poslad and Calisti (2000) [9] examined the notions of trust and security inherent in the core FIPA specifications. *They highlighted that there is still no coherent and complete picture for agent security within FIPA at this point, the implicit assumption in FIPA security management is that agents are co-operative and trustworthy and that agent security is responsibility of the infrastructure in which it is embedded.*

Mass & Shehory (2001) [15] introduced architecture for implementing trust establishment mechanism in common agent architectures. Maximilien and Singh (2001) [4] proposed Web Service Agent Proxy (WSAP) based reputation and endorsement mechanism. However their approach doesn't address challenge of accountability of agents and also implementation of the proposed framework is left as part of future work. Alibhai (2003) [2] elaborated the role of CNP in complex, truly distributed environments emphasizing CNP as life force of distributed systems. Maamar, Sheng & Benatallah(2003) [6] proposed deployment of agents for composition and execution of web services , although they have not considered the reliability or trustworthiness of the agents employed. Paes, Almeida, Lucena & Alencar (2004) [8] proposed FROG to enforce secure interaction protocols in MASs. Tsai, Zheng, Chen, Huang, Paul and Liao (2004) [12] proposed service oriented software reliability model for atomic and composite web services. Agerri & Alonso (2005) [1] proposed rights based framework that mainly focuses on communication semantics and the pragmatics. However, it

[1] http://www.fipa.org

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fails to cover other patterns of conversations and mechanisms to punish violations. Huynh, Jennings & Shadbolt (2006) [5] presented a trust and reputation model called FIRE based on the assumption that agent report their trust information truthfully which is not possible in open, dynamic MAS. Wang & Singh (2007) [13] presented a theoretical development of trust that would work in variety of situations where evidence based trust reports are desired. Their work contributes a mathematical understanding of trust. However extension of this work from binary to multi-valued events is left as part of future work. Novak (2008) [7] highlighted FIPA complying platforms are not suitable for development of open heterogeneous MASs. Wu (2008) [14] proposed a norm based CNP for improving the efficiency and effectiveness of the coordinating processes in a MASs. Singh, Juneja & Sharma (2010) [10] proposed a variation of CNP incorporating trust establishment mechanism into it, thereby facilitating agents to have initial trust with their communicating counterparts, however ensuring reliability of those trusted agents is still left.

The literature survey presented above highlights that researchers had been recommending for trust establishment mechanisms in agent communication and some variations in CNP has also been proposed. However, reliability of communicating agents is completely ignored. Reliability of communicating agents has not been paid any attention so far, although it's an equally essential dimension to be focused upon. Both CNP and CNTEP work on broadcast-based communication strategy, thus even after ensuring the trustworthiness of task agents, they may come out to be unreliable leading to wasted efforts. On the other hand delegating the task to trustworthy and reliable agents will improve the probability of successful task completion, resulting in enhanced customer satisfaction.

Next section elaborates the proposed new variation of CNTEP involving agent reliability computation mechanism, thereby termed as *Reliable Contract Net Trust Establishment Protocol (RCNTEP).*

III. Proposed Work

Reliability and trust are two important dimensions for ensuring efficient and fruitful agent communications in dynamic, open and distributed environments such as Internet. In such open environments agents are created by variety of stakeholders for various purposes and they may join or leave MAS dynamically depending on their own motives. Thus there is large possibility that the agents involved in communications and in providing services are likely to be un-reliable, self-interested and possessed with incomplete knowledge. Agent reliability is further degraded by the fact that they are intelligent and may change their plan of action depending on their motives and intentions, which also keep on changing with time. In the light of above facts, credibility of the agents becomes questionable and leads to necessity of a mechanism for ensuring credibility of the agents before delegating task to them. To meet above stated needs, a reliable contract net trust establishment protocol (RCNTEP) has been proposed in existing CNTEP to help monitor and select effective communication partners. Before proposing the main RCNTEP, following basic terms must be understood:

- ***TPC:*** TPC stands for *Trust Percentile Certificate* that is official document of trust for an agent generated by CNTEP. Without this document no agent is permissible to send their bids to composite/initiator agent.
- ***Bid_Packet:*** *Bid_Packet* is a combination as given below: *Bid_Packet= <Agentid, Condition,Cost,Time_Required,Bid,TPC>*
- ***Bid_Record_Table:*** It maintains the record of all *Bid_Packet*s received for a particular proposal. For every proposal, initially it is empty and it is populated with the information from *Bid_Packet*s arriving subsequently.
- ***Agent Reliability Table:*** This table contains the reliability parameter values for *Atomic_Agents*. It comprises of *TPC*, *Reliability Value* (*RV*), *Conditions* and *Time*.
- ***RV:*** *RV* stands for *Reliability Value* of participating agents, calculated by initiator agent. It ranges between possible set of values that is {…..-2,-1, 0, +1, +2…..}. If *RV* of an *Atomic_Agent* exceeds the negative threshold value, the corresponding *Atomic_Agent* is permanently blocked from bidding.
- ***Condition:*** *Condition* refers to the constraints imposed on the task performance by the composite agent (CA). These conditions has to be taken care of by *Atomic_Agent* while executing the task.
- ***Result:*** Result specifies the information (material) and its format to be provided by *Atomic_Agent* to the CA after the task is successfully executed. Result of task execution may be either complete, incomplete or failure_to_complete. A task successfully completed is indicated by OK entry in ART, incomplete or failure_to_complete is indicated by NOK entry.
- ***Time:*** Time is the total duration required for the completion of the task. This attribute can take three possible values: *Max* for utmost time, *Min* for less time and *Mod* for moderate timing. The composite agent will decide the range for *Max*, *Min* and *Mod* depending upon the task to be delegated.

In RCNTEP participating agents are *Atomic_Agents* and *Composite_Agents* (CA). *Atomic_Agent* performs a specific task independently and do not further divide the same, whereas *Composite_Agent* itself comprises of various *Atomic_Agents* and provides a service to the user by dividing it among atomic agents. Thus it depends on these atomic agents for accomplishment of its task. Figure 1 provides the high level view of RCNTEP where CA_i is a composite agent that is further composed of atomic agents named $Atomic\_Agent_{1\ldots\ldots}$ $Atomic\_Agent_i$………$Atomic\_Agent_{n.}$ These *Atomic_Agent*s are answerable to their corresponding *Composite_Agents*. Whenever there is a task to be performed, *Composite_Agent* generates a call for proposal and sends it to *Atomic_Agents* associated with it. The interested *Atomic_Agents* proceed for bid submission. Before submitting their bid *Atomic_Agent* initiates CNTEP to get its TPC (the procedure for computing trust percentile has already been discussed in [10]). Since the focus of this work is to

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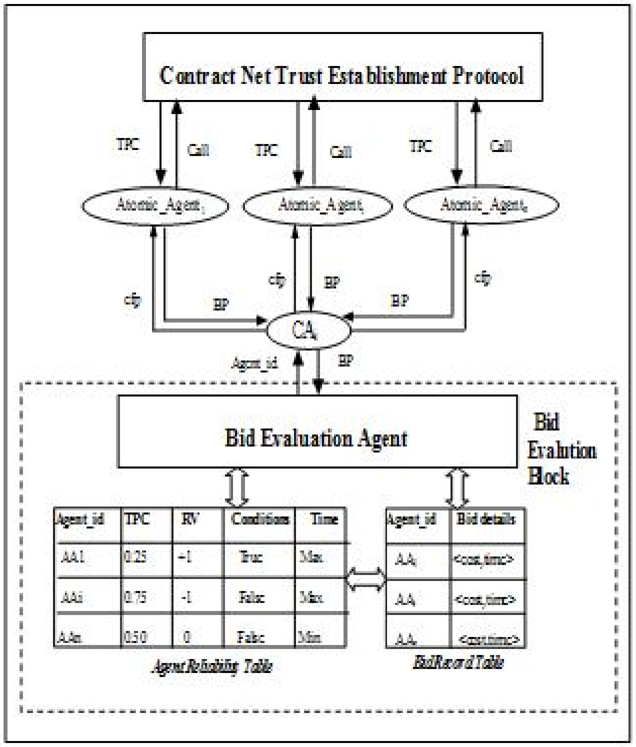

Figure 1. High Level View of RCNTEP

compute the reliability of a participating agent which is based on the exisiting design of CNTEP, it is only after getting the TPC, *Atomic_Agent* generates a *Bid_Packet* and submits the same to *Composite_Agent* which in turn forwards it to Bid Evaluation agent (BEA). BEA is supported with two data structures namely *Bid_Record_Table* and *Agent_Reliability_Table* which help in bid evaluation and reliability assessment. When an *Atomic_Agent* interacts with this system for the first time, an entry for it is created in *Agent_Reliability_Table* with its initial TPC value. In contrast, if an *Atomic_Agent* has earlier interacted with the system its entry exists in *Agent_Reliability_Table* illustrating its past behavior and the TPC value is updated in the same record.

Reliability Value of an agent refers to its credibility for *Composite_Agent*. When an *Atomic_Agent* interacts with *Composite_Agent* for the first time its RV is set to 0 i.e. unknown since the *Atomic_Agent* is yet to prove its credibility. Once a task is delegated to an *Atomic_Agent* and it successfully completes it, *Composite_Agent* increases its RV value by 1 i.e.

$$RV=RV+1 \tag{2}$$

Whereas if due to any reason agent doesn't complete its task within specified time its RV is decremented by 1 leading it to

$$RV=RV-1 \tag{3}$$

When RV of an *Atomic_Agent* reaches threshold of negative RV (assumed to be -5, in this case), it is debarred from further bid submission. However if an agent gets negative RV, it may improve its performance next time and get its RV changed to positive side. BEA give least priority to *Atomic_Agent* having negative RV, but in certain cases when no other *Atomic_Agent* is free/interested in bid submission or no other *Atomic_Agent* is capable for a specific task, BEA is forced to consider less reliable *Atomic_Agent* giving it a chance to improve its reliability for future.

Conditions and Time entries are populated once the task is delegated to *Atomic_Agent* and is completed by it. On successful completion *Composite_Agent* analyzes whether *Atomic_Agent* satisfied all the imposed constraints and the time it consumed. Time is analyzed and entered in ART even on unsuccessful completion.

B. Working of RCNTEP

The working of RCNTEP is explained in figure 2. As can be seen, the working of RCNTEP is divided in eleven steps. These steps are explained as follow:

1 *Composite_Agent* generates *cfp* and sends it to all possible *Atomic_Agents* who might be interested in that *cfp*. CA might consult the directory listing the functionality of *Atomic_Agents*.
2 On receiving *cfp*, the *Atomic_Agents* are not permitted to respond back immediately to *Composite_Agent* unless and until they possess the *TPC* from CNTEP. Thus for getting *TPC Atomic_Agents* call CNTEP. For detailed working of CNTEP, refer to [9].
3 CNTEP returns *TPC* to all atomic agents ($Atomic\_Agent_{1}$...... $Atomic\_Agent_{i}$........ $Atomic\_Agent_{n}$) after calculating their trust percentile.
4 After getting *TPC* the *Atomic_Agent* makes a packet of *TPC* and its *bid* and sends this *Bid_Packet* to the concerned *Composite_Agent*.
5 *Composite_Agent* forwards all *Bid_Packets* to BEA demanding for the most reliable agent.
6 BEA records every *Bid* in *Bid_Record_Table* and enters *TPC* value in *Agent_Reliability_Table*.
7 When bid submission date expires, BEA first analyses *Bid_Record_Table* to shortlist the *Atomic_Agents* having least cost and time specification. Then it accesses *Agent_Reliability_Table* to compute the most reliable agent among all the candidate agents.

Evaluation process is based on various parameter values like high TPC, high RV, fulfillment of specified conditions and minimum time duration and above all successful completion of earlier designated tasks. A *reliability_score* is computed for every shortlisted agent using the formula:

$$Reliability\_score = \sum_{n=1}^{\infty}(TPC + RV + conditions + Time + Results) \tag{4}$$

Where

- n represents the number of interactions agents have had with the system.
- conditions are interpreted as either True (1) or false (0)
- Time shall be interpreted as {Max=-1, Moderate =0 , Min=+1}
- Results are interpreted as {Complete=+1, Failure=0 , Incomplete=-1}

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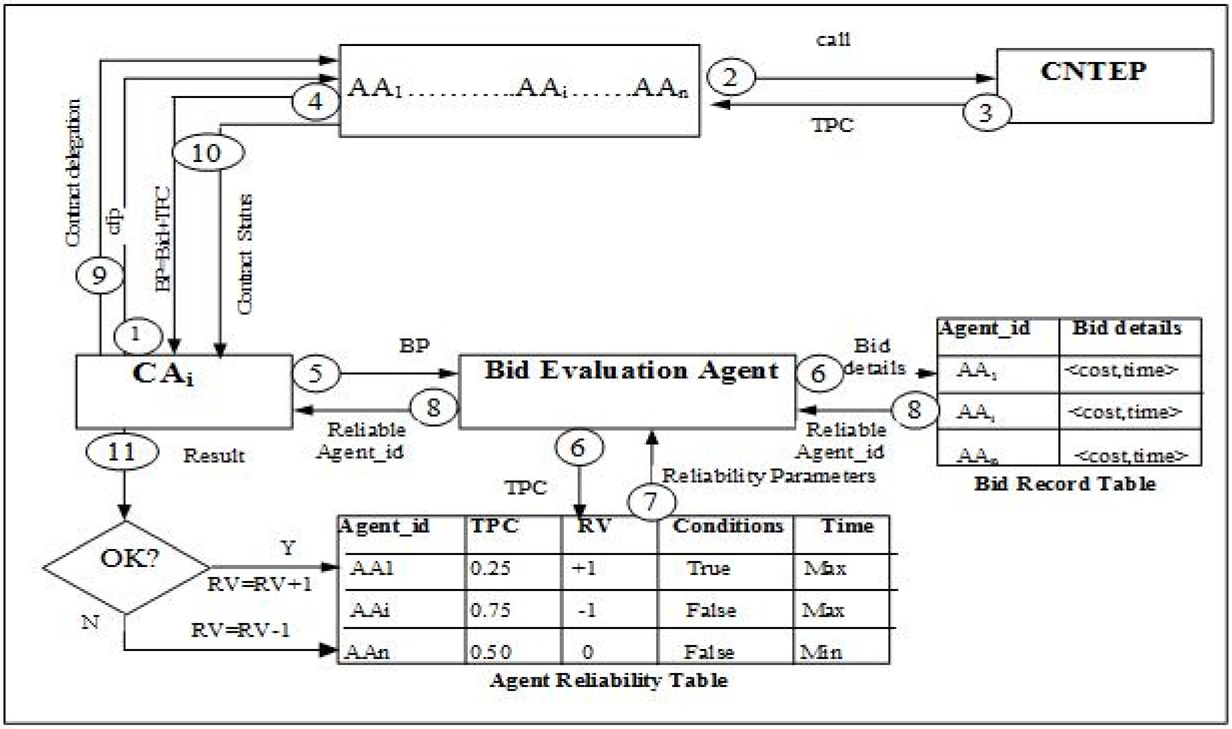

Figure 2. Architecture of RCNTEP

Once the reliability score is available for appealing agents, most reliable agent is selected based on highest reliability score:

$$Reliable\_Agent=Max(Reliability\_score) \quad (5)$$

In case of more than one agent having highest reliability_score, the agent who submitted the BP first is chosen for task delegation.

8 The BEA returns most reliable agent_id to *Composite_Agent*.

9 *Composite_Agent* then awards the task to *Atomic_Agent* nominated by BEA through step 8.

10 The awarded *Atomic_Agent* is required to inform the status of designated task to *Composite_Agent* within a specified period.

11 If the *Composite_Agent* is satisfied with the results supplied by *Atomic_Agent* then it increases RV by +1 otherwise decrease it by 1. These values are updated in the *Agent_Reliability_Table* for future use.

The figure 3 given below provides the flow diagram of RCNTEP.

The algorithms of various agents involved in RCNTEP are given in figures 4(a)-4(d) below:-

C. Result Analysis

For testing the proposed work a prototype of the above framework was developed in JADE. The results of execution of RCNTEP are compared with execution of CNTEP and significant improvement in efficiency of task execution has been observed. The figures 5(a)-5(d) given below illustrate the difference in performance of CNTEP and RCNTEP. Although CNTEP placed limit on the number of contractors which can be considered for task delegation, in contrast to

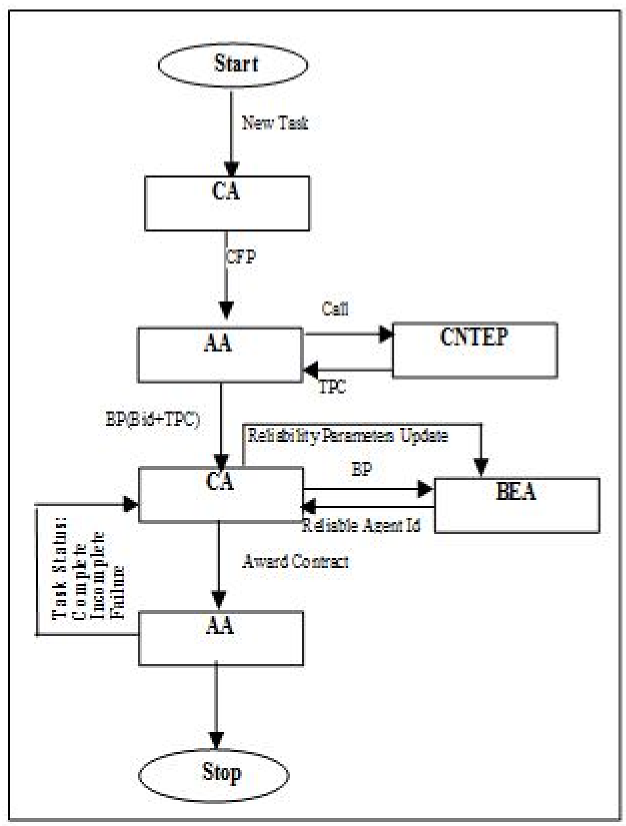

Figure 3. Flow Chart of RCNTEP

standard CNP (see fig. 5(a) below), but due to lack of reliability feature success rate of task performance was not improved much.

Now with introduction of reliability computation mechanism, number of contractors considered for task

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```
Composite Agent ( )
Input: new task;
Output: cfp, award contract message, task (results);
 { on(new task) activate;
    generate cfp;
     activate Atomic_Agent (cfp);
     while (Not(deadline))
       { receive Bid_Packet ← Atomic_Agent ;
          activate BEA;
         BEA ← Bid_Packet ;     }
     receive reliable (agent_id) ←BEA;
    reliable (agent_id)← award contract;
   receive results(agent_id);
     if (results==Ok)
          { RV=RV+1; return(results);}
          else
         RV=RV-1;
 }
```

Figure 4(a) Algorithm for Composite Agent

```
Atomic_Agent ( )
Input: cfp;
Output: Bid_Packet, results;
{   on( cfp) activate;
  if(interested(cfp)
  {   enter cfp in list;
    get TPC H Execute ( CNTEP);
    generate Bid;
    create  Bid_Packet=Trust_Percentile_Cretificate  +
                                  Bid;
    return (Bid_Packet);
 }
 else sleep;  }
```

Figure 4(b) Algorithm for Atomic Agent

delegation is further reduced (shown in figure 5(b) below). It is clear from the graph below that number of contractors has been reduced considerably.

However, performance analysis of CNTEP and RCNTEP clearly highlights that with RCNTEP the success rate of task execution & completion improves significantly. Since with RCNTEP, only reliable contractors are considered for task delegation, which saves bandwidth consumption in managing

```
Bid_Evaluation_Agent ( )
Input: Bid_Packet;
Output: reliable (agent_id);
{  if (Not(deadline))
    {on (Bid_Packet ) activate;
    Enter      values      in      Bid_Record_Table      &
Agent_Reliability_Table ;}
   on(deadline)
   { Analyse Bid_Record_Table to shortlist Atomic_Agents;
   for ∀ Atomic_Agents
  { compute reliability  score from Agent_Reliability_Table:
     Reliability_Score= ∑_{n=1}^{∞}(TPC + RV + conditions +
                          Time + Results);
}
Reliable _Agent= Max (Reliability_score);
return (reliable_agent_id);}
```

Figure 4(c) Algorithm for Bid Evaluation Agent

```
RCNTEP ()
Input: New Task
{
     Activate Composite_Agent_i (New Task);
}
```

Figure 4(d) Algorithm for RCNTEP

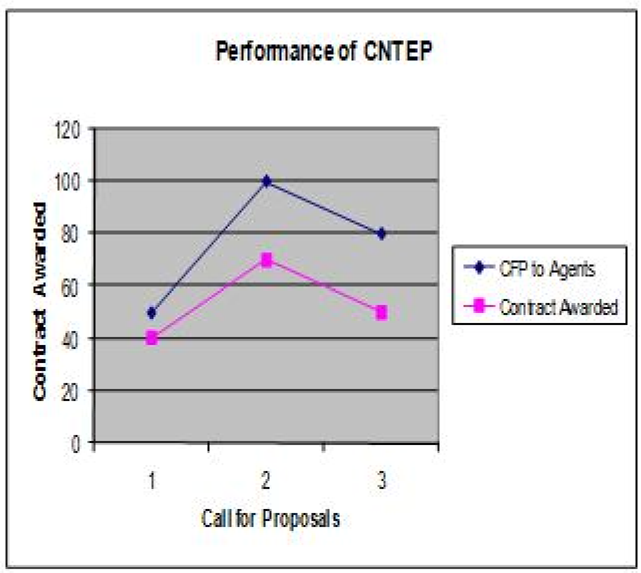

Figure 5(a) Performance of CNTEP in Terms of Task Delegation

failed contracts, provides timely results to the end users and improves quality of service.

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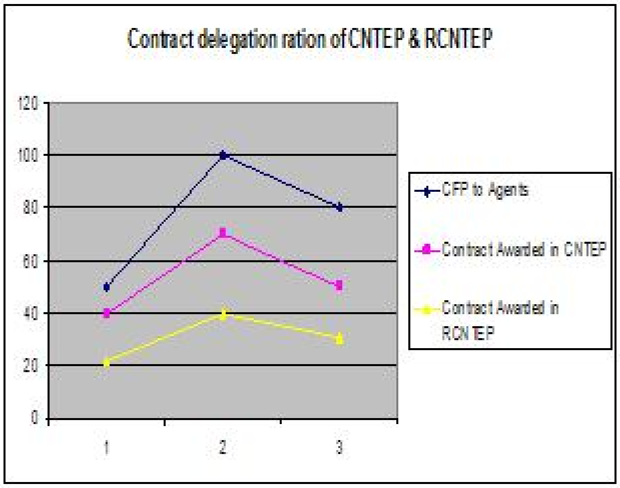

Figure 5(b) Contract Delegation Ratio of CNTEP & RCNTEP

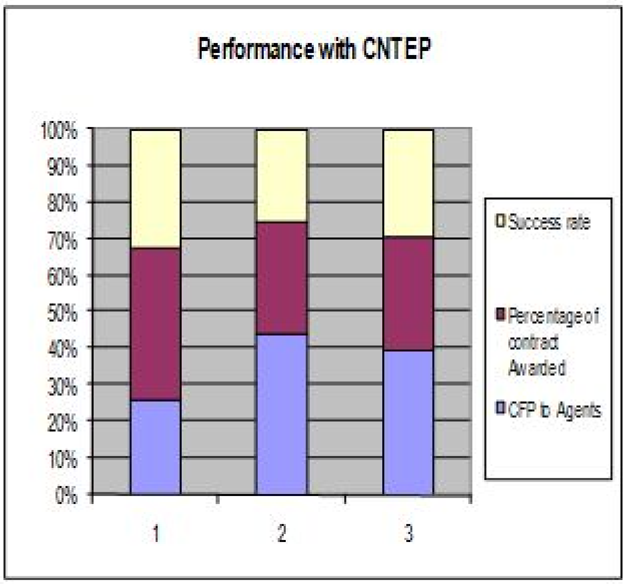

Figure 5(c) Performance with CNTEP

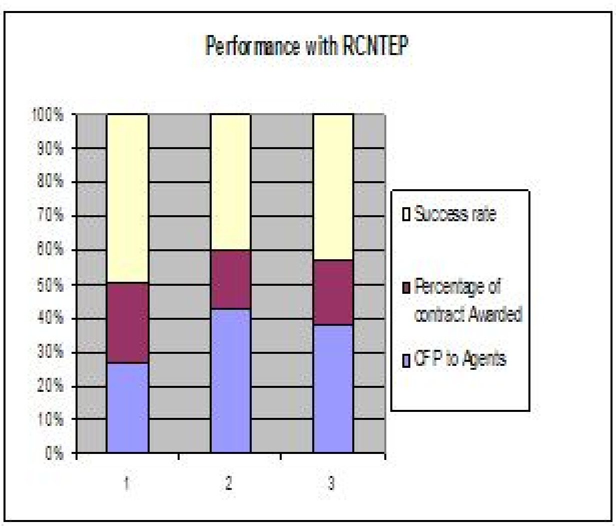

Figure 5(d) Performance with RCNTEP

Conclusions

This work has presented a new variation of already proposed Contract Net Trust Establishment Protocol (CNTEP) by incorporating reliability computation mechanism in it. The obtained results were analyzed in terms of task performance and significant improvement could be observed in terms of successful task completion, timely response to the user and better bandwidth utilization by reducing contract failures. Thus this work significantly improved task performance mechanism of agents in comparison to the traditional CNP.

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